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REPORT #
RRTAC 91-2

Winter Soil Evaluation and Mapping for Regulated Pipelines

Heritage Fund

Alberta
LAND CONSERVATION AND
RECLAMATION COUNCIL
Reclamation Research
Technical Advisory Committee

Alberta's Reclamation Research Program

Regulating surface disturbances in Alberta is the responsibility of the Land Conservation and Reclamation Council. The Council executive consists of a Chairman from Alberta Environment and two Deputy Chairmen from Alberta Forestry, Lands and Wildlife. The Council oversees a reclamation research program, established in 1978, to identify the most efficient methods for achieving acceptable reclamation in the province. Funding for the research program is provided by Alberta's Heritage Savings Trust Fund, Land Reclamation Program.

To assist with the development and administration of the research program, the Council appointed the inter-departmental Reclamation Research Technical Advisory Committee (RRTAC). The Committee consists of eight members representing the Alberta Departments of Agriculture, Energy, Forestry, Lands and Wildlife, and Environment, and the Alberta Research Council. The Committee updates research priorities, reviews research proposals, organizes workshops, and otherwise acts as the coordinating body for reclamation research in Alberta.

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REPORT #
RRTAC 91-2

WINTER SOIL EVALUATION AND MAPPING FOR REGULATED PIPELINES

by

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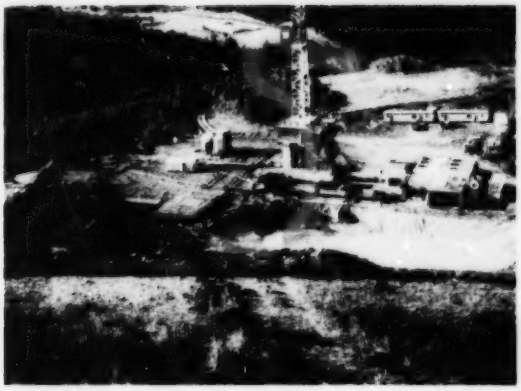
Prepared for

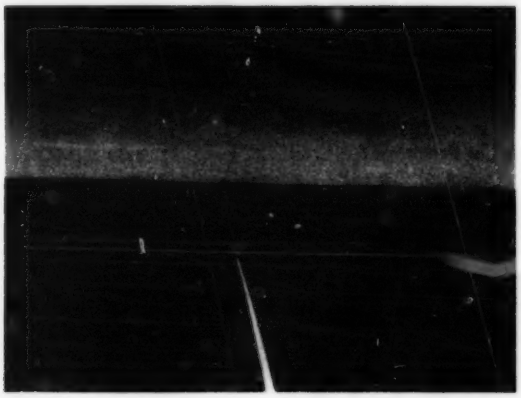
Canadian Petroleum Association

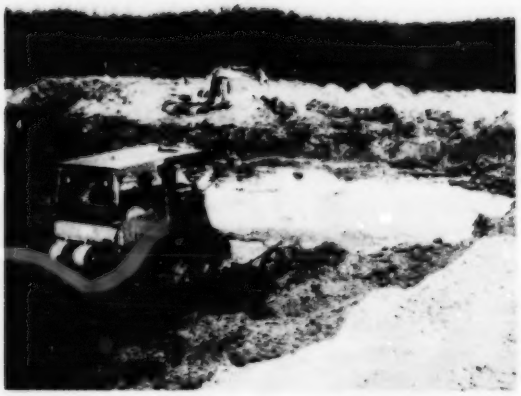
and

ALBERTA LAND CONSERVATION AND RECLAMATION COUNCIL
(Reclamation Research Technical Advisory Committee)

Oil and Gas Reclamation Research Program







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DISCLAIMER

This report is intended to provide government and industry staff with up-to-date technical information to assist in the preparation and review of Development and Reclamation Approvals, and development of guidelines and operating procedures. This report is also available to the public so that interested individuals similarly have access to the most current information on land reclamation topics.

The opinions, findings, conclusions, and recommendations expressed in this report are those of the author(s) and do not necessarily reflect the views of government or industry. Mention of trade names or commercial products does not constitute endorsement, or recommendation for use, by government or industry.

As noted in this report, the regulatory agencies prefer to see soil evaluations for pipeline planning done under non-winter conditions.

REVIEWS

This report has been reviewed by members of the Reclamation Research Technical Advisory Committee, and by the Oil and Gas Reclamation Research Program Committee. RRTAC also thanks Fred Kuipers, Peace Pipe Line Ltd, who reviewed the document for the Canadian Petroleum Association, and Travis Ferguson, who reviewed the document for the Land Conservation and Reclamation Council.

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ABSTRACT

A soil evaluation is required in support of a Development and Reclamation (D & R) Application where arable land, potentially arable land or pasture land is disturbed. The evaluation is to provide information about the soils and landforms along a proposed pipeline route to assist in soil conservation planning for pipeline construction. Recently there have been some concerns regarding the validity and accuracy of performing winter soil evaluations for regulated pipelines. Discussions were held with staff in various government departments and industry, and with consultants who are associated with or affected by winter soil evaluations for regulated pipelines.

The most serious constraints identified in conducting winter soil evaluations are the ability of the pedologist to distinguish horizons and classify soils properly when there is poor light and when frozen conditions occur in the subsoil; and, the ability of the pedologist to map accurately when the vegetation and landscape are masked by a covering of snow. **If possible, soil evaluations should be scheduled for summer.** If this is not possible, the evaluation can be carried out under less than ideal conditions in the winter. Some specific soil parameters may be difficult to measure or determine when the soil is frozen, and the site inspection and sampling density may have to be increased substantially. Topsoil depth, land use, and the characteristics and quality of the topsoil and upper and lower subsoils are important parameters that have to be documented in soil evaluations for pipelines. Salt-affected soils are of prime concern. These soils are easily recognized when only the topsoil is frozen but may be difficult to recognize if frost has penetrated deep into the subsoil.

Relative degrees of difficulty in carrying out winter (or summer) soil evaluations in the province have been identified. The depth of frost, the type of soils that are likely to be encountered, the experience of the pedologist, the amount and type of soils information already available, and the type of equipment that will be used to inspect the soils are factors that have to be considered on a project-by-project basis, prior to initiation of a winter soil evaluation.

ACKNOWLEDGEMENTS

Sincere appreciation is extended to the many individuals who contributed their thoughts and ideas to this manuscript. A list of individuals who participated in discussions is presented in the Appendix.

Further, thanks are extended to K. Bessie, L. Knapik, N. Finlayson, and L. Leskiw for reviewing the document and providing constructive criticism. Appreciation is expressed to B. Seager, T. Brierley and T. Ferguson for organizing specific discussion groups.

Funding has been provided by the Alberta Heritage Savings Trust Fund Land Reclamation Program through the Alberta Land Conservation and Reclamation Council, and the Pipeline Division of the Canadian Petroleum Association.

1. INTRODUCTION

A soil evaluation is required in support of a Development and Reclamation (D & R) Application where arable land, potentially arable land or pasture land is disturbed (Alberta Environment 1988). The evaluation is to provide information about the soils and landforms along a proposed pipeline route to assist in soil conservation planning for pipeline construction. Proper soil conservation planning is necessary to ensure that equivalent soil capability is maintained following disturbance. Industry is responsible for planning proper conservation procedures, based on a thorough evaluation of the soils.

Winter conditions in Alberta last for about four months (December to March) of the year. Recently, there have been some concerns regarding the validity and accuracy of winter soil evaluations for regulated pipelines. The objective of this study is to outline issues surrounding, and methods for, winter soil evaluations for assessing pipeline material handling procedures. Since soils are only inspected and mapped along a transect, rather than on an area basis, soil specialists object to the term 'soil survey' being used to describe a soil inventory along a pipeline route. Therefore a soil inventory along a pipeline route will be referred to as a soil evaluation rather than a soil survey for the purposes of this report.

Discussions were held with staff in various government departments and industry, and with consultants who are associated with or affected by winter soil evaluations for regulated pipelines. The issue to some people is not whether a soil evaluation can be carried out under frozen conditions; the issue is can you get the information required by the regulators to make proper material handling decisions? What are the consequences if a soil is not classified properly? Material handling decisions are based on soil characteristics, present land use and types of construction equipment available. Soil parameters important in material handling decisions are sodium adsorption ratio (SAR), electrical conductivity (EC), texture, topsoil depth, depth to saline, sodic or texture change, and soil variability within a map unit. Electrical conductivity and SAR can only be reliably obtained by laboratory analysis. Texture can also be obtained by laboratory analysis. When carrying out soil evaluations in frozen

ground: one can readily see salts below the frozen layer, and with closer inspection of the frozen layer can measure at what depth they are encountered (laboratory analysis will confirm the degree of salinity); one can see sands and gravels and can measure what depth they are encountered; but, one cannot reliably make an evaluation for SAR. Sodium adsorption ratio can only be confirmed by laboratory analysis, regardless if samples are collected under frozen or non-frozen conditions.

This document discusses the concerns related to carrying out winter soil evaluations and provides procedures, alternatives and suggested guidelines to alleviate concerns.

2. DEFINITION OF WINTER SOIL CONDITIONS

There are various concepts of what constitutes winter conditions during a soil evaluation. Some people define winter conditions as occurring only when soils are frozen into the subsoil and do not consider snow cover as a limiting factor. Others define winter conditions as occurring when either snow or frost is present at the time of field investigations and consider poor light and difficulty in distinguishing colours as important limitations. Others place their emphasis on the ability of the pedologist to interpret the landscape properly and delineate map units accurately when there is a lack of vegetative cover and the terrain is masked by considerable depth of snow. There is no question that the depth of frost in the soil profile and the amount of snow cover on the surface cause some difficulty in carrying out soil investigations and mapping. Poor light can make colour differentiation of horizons difficult and will occur in the winter regardless of snow or frost conditions. Poor light is caused by low light levels and by the sharp contrast between bright, reflected light from the snow and the dark soil hole. Deep snow may restrict access and mask landscape surface characteristics such as stoniness and vegetation, but can be easily mitigated by snow plowing. Poor light can be somewhat mitigated by restricting the time of day at which field investigations are conducted. A more serious constraint is the depth of frost into the soil profile. Soils that are frozen to considerable depth may pose some limitations in identifying horizons, depths of horizons, texture, structure, and consistence, while frozen conditions to a depth of 10 to 20 cm pose little or no limitations in identifying subsoil horizons, texture, structure, and consistence because lower horizons are not frozen.

There is a misconception that soils freeze to a great depth (greater than 1 m) during the middle of winter. Although moisture content, snow cover, land use, and texture affect depth of frost penetration, frost is rarely encountered below the 70 cm depth even after prolonged periods of very cold weather. In fact, soils are seldom frozen below the 50 cm depth if there is vegetation on the surface and there is 50 cm or more of snow on the surface. Frost

penetration into the soil profile is deepest in areas that have no vegetation or snow cover on the surface.

Since the depth of frost is considered as the most serious constraint during field investigations, for the purposes of this report winter conditions are defined as occurring when the soils are frozen into the subsoil over the majority of the pipeline route. It is recognized that poor light and depth of snow may limit operations and require modified procedures.

3. GOVERNMENT AND INDUSTRY POSITIONS REGARDING WINTER SOIL EVALUATIONS

Government would like industry to confine soil evaluations for regulated pipelines to non-frozen soil conditions. Government feels that the information gathered for the D&R Application during a winter soil evaluation may not be valid or accurate enough for planning proper soil conservation procedures. Their main concerns are: poor light, that results in difficulty in identifying horizons and colours; frozen conditions, which make it difficult to differentiate topsoils from subsoils, identify horizons, define horizon depths, and classify the soil properly; snow cover, which masks landscape and vegetation features, and hinders soil mapping; and, a winter soil evaluation cannot be readily field checked by government personnel. Although government prefers that soil evaluations be conducted under non-frozen conditions, they realize that occasionally a soil evaluation will have to be carried out under winter conditions. If a winter soil evaluation has to be conducted, government would like the evaluation to be carried out by a very experienced and qualified pedologist.

Although industry recognizes some of the concerns in carrying out a winter soil evaluation, and they try to schedule soil evaluations when the soils are not frozen, they would like to have the option to carry out a winter soil evaluation if the need arises. Industry realizes that a winter soil evaluation generally has a higher cost than a summer evaluation, so it is to their economic advantage to carry out soil evaluations prior to winter. They have no concerns with increasing the site inspection density or sampling density if the need arises.

Industry expressed some concern in the length of time required to review a D & R Application, especially when timing is critical. It may be possible to eliminate some winter soil evaluations if the review period was reduced. A pipeline scheduled for construction in May or June presently requires a soil evaluation during the winter with the present six-week review period, but if the review period was reduced to three or four weeks the soil evaluation could conceivably be carried out in early spring when the soils are not frozen. However, in early

spring a situation may arise where the soils are wet, and if a drill truck is required for soil inspections, rutting may occur.

4. EQUIPMENT COMMONLY USED FOR WINTER SOIL EVALUATIONS

The type of equipment that can be used for winter soil evaluations depends on access and the depth of snow and frost. Some years ago, soil excavations were made with pick and shovel through the frozen layer, and hand augers below the frozen layer. This method was time-consuming and very strenuous on both personnel and equipment. Today soil inspections are generally carried out with a mechanical drill mounted on a heavy-duty 4 x 4 truck, although hand augers still have to be used in forested areas that are not accessible with a drill truck.

The mechanical drill generally utilizes one of two methods to inspect the soil; the core-barrel method or the rotating auger method. In the core-barrel method, a 5 or 8 cm steel core barrel is hydraulically pushed into the soil and pulled vertically up and out of the soil. The core-barrel method has advantages over the rotating auger method in that it causes little or no disturbance to the soil profile. A 5 or 8 cm core is extracted and the morphological characteristics of the soil can be described. However, some difficulty arises in attempting to obtain a core when the soils are very stony or gravelly and when the frost depth exceeds 30 cm (although one drilling company reports they can obtain an 8 cm core at frozen depths of 70 cm).

The rotating auger method utilizes rotation to excavate the soil sample. A 10 or 15 cm auger is screwed into the ground with minimal disturbance and pulled vertically up and out of the soil (see Figure 1). The morphological characteristics of the soil profile are described on the auger. Some disturbance of the soil profile occurs using this method, but it has an advantage over the core-barrel method in that it can penetrate through a deeper frozen layer and can rotate through stony and gravelly layers. Most of the disturbance occurs in the topsoil horizon that is generally frozen. The depth of topsoil may have to be obtained from the side of the drill hole, especially if a great deal of disturbance has occurred. Most drill trucks used today are capable of carrying out both augering and coring and sometimes a combination of the two methods is used at a site.

Figure 1. Rotating Auger Method to Excavate the Soil Profile.

The drill truck must be capable of driving through a considerable depth of snow. If snow conditions become too deep it may be necessary to have the proposed route snow-plowed. It is also necessary to have all pipeline crossings clearly marked in the field since the drill truck is capable of puncturing a 'hot line'. Legal surveyors either precede the soil surveyor or accompany the drill truck to clearly mark 'hot lines' in the field.

In forested areas that are not accessible by drill truck the soil excavation has to be carried out manually. Fortunately, frost penetration in forested areas seldom exceeds a depth of 30 cm because of the insulating properties of the forest vegetation. Experience has shown that the best method to make an excavation is to use two types of hand augers. A heavy 'gravel head auger' is used to excavate the frozen layer (Figure 2), then a 'normal head auger' (Figure 3) is used to excavate the material below the frozen layer. Sometimes it may be necessary to probe the frozen layer with a crowbar to loosen the frozen material so that the 'gravel auger' can bite into the frozen material. Sometimes an overthrown tree stump in the forest can be viewed to see the soil profile.

Figure 2. A Heavy "Gravel Head" Hand Auger used to Excavate the Frozen Layer.

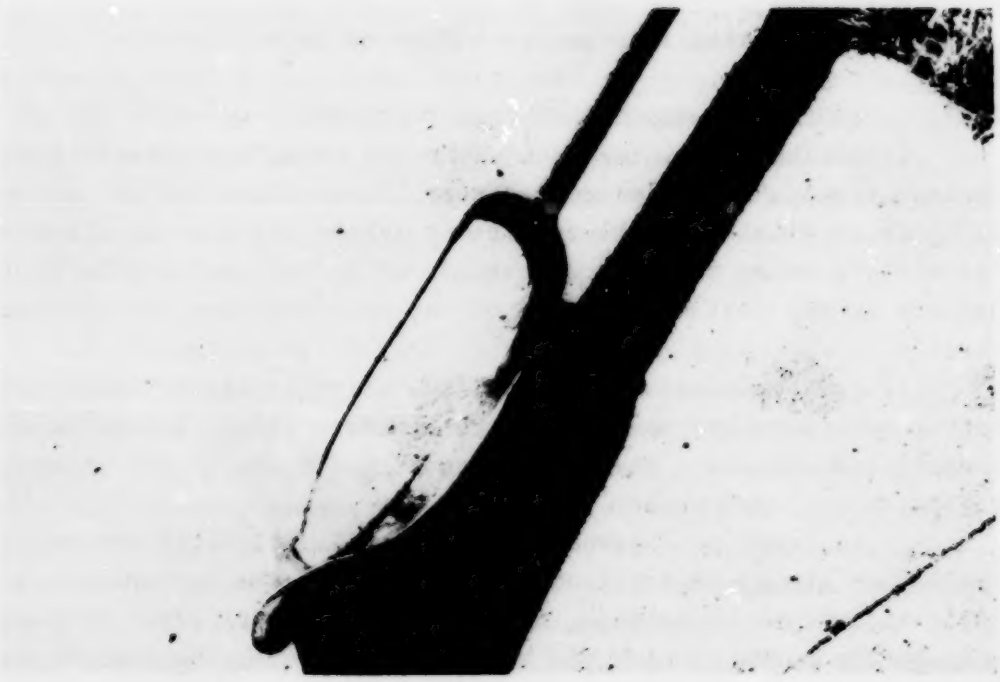

Figure 3. A "Normal Head" Hand Auger used to Excavate the Soil below the Frozen Layer.

5. SPECIFIC CONCERNS IN WINTER SOIL EVALUATIONS

Through discussions with soil specialists, a number of specific concerns have surfaced with respect to carrying out winter soil evaluations for regulated pipelines. Some of the concerns are valid and cannot be completely eliminated, but some can be mitigated by using alternative techniques or procedures. The major concerns and mitigation measures, if any, are addressed below.

5.1 POOR LIGHT AND COLOUR IDENTIFICATION

During the winter months the sun is at a low angle to the horizon and light conditions are poor. Poor light may be more profound if there is glare from the snow cover. Poor light is at its worst in the early morning and late afternoon and is more noticeable for longer periods in the northern portion of the province than the southern portion.

Soil colours are obtained by "Munsell Colour Notations". Colour notations are used mainly to indicate colour change between topsoil and subsoil. This is important information that should be passed on to construction personnel.

In order to somewhat offset poor light levels the soil evaluation should be confined to that part of the day which has more favourable light conditions, namely, from one hour after sunrise to one hour before sunset during the winter months. This may substantially reduce the length of the working day, especially in the northern portion of the province. Another method to mitigate for poor light is to collect samples and obtain colours where light conditions are favourable. It has also been suggested that colours could be determined under a halogen light in the field.

5.2 DIFFERENTIATING TOPSOIL FROM SUBSOIL

Differentiating topsoil from subsoil only becomes a concern when a core cannot be obtained and the soils are frozen into the subsoil. When these conditions occur, the soil profile may have to be inspected by the rotating auger method. If there is good colour differentiation of topsoil from subsoil then the depth of topsoil can be obtained by colour differentiation. If topsoil cannot readily be

distinguished from subsoil by colour on the auger, then the depth of topsoil can be obtained by inspecting the side of the auger hole and the material that is obtained from the hole in shallow depth increments. Sometimes a lighter coloured Ae horizon occurs between the topsoil and subsoil which will aid in differentiating topsoil from subsoil.

Differentiation of topsoil from subsoil in cultivated fields can be done by closely examining the material. Topsoil (Ap horizon) generally has straw or other plant material incorporated into it while the subsoil is void of straw or other plant material. If a straw or hay bale is nearby, a core or auger hole can be easily obtained under non-frozen conditions by pushing the bale to the side. The soil seldom freezes beneath a bale.

5.3 IDENTIFICATION OF TEXTURE, STRUCTURE AND CONSISTENCE

Texture, structure and consistence are not always critical soil parameters required for classification, and these parameters are usually generalized in the soil unit description. Therefore, it is not essential that these parameters be accurately described in the field at each inspection site because they frequently have little bearing on material handling procedures. These parameters only become important when there are strongly contrasting differences at depth in the profile, which may result in a change in material handling procedures.

Broad textural groupings can be made even if the material is frozen. Clays can be distinguished from sands but clay loams are not readily distinguished from loams. If accurate textural classes are required then samples should be collected for laboratory analyses, or samples can be collected and thawed prior to hand texturing.

Structure and consistence are more difficult to obtain when the soil materials are frozen. Structure is generally obvious if a core can be obtained but the structure may not always be obvious if the rotating auger method is used. If the auger can be screwed into the soil in short depth increments without over-rotation, then the structure of the horizon can be obtained.

Consistence cannot be determined when the material is frozen but can sometimes be inferred from texture. Sands are generally very

friable to loose while clays are firm or very firm. Frequently only the upper B horizon is frozen and the lower B horizon is not frozen. Texture, structure and consistence can then be obtained from the non-frozen portion of the B horizon.

5.4 IDENTIFICATION OF SALT-AFFECTED SOILS

Before the soil evaluation is initiated, it is important to determine from existing literature if the proposed route has any salt-affected soils in the general region. There are many areas in the province which do not have salt-affected soils and it is highly unlikely that they will be encountered in specific areas in these regions. If salt-affected soils are suspected along the proposed route the sampling density should be increased by about 50 percent.

Salt-affected soils include a variety of Solonetzic and Chernozemic soils. Examples of Solonetzic soils include the Camrose and Killam soil series. Solonetzic soils are characterized by dark colours, very firm consistence, and columnar or prismatic structure in the Bnt horizon. The underlying Csk horizon may or may not have visible salts. The horizons and structure are fairly obvious in a core. The horizons and structure may not be obvious in an auger, and samples should be collected for laboratory analysis. The key to identification of a frozen Solonetzic profile is the dark colour and prismatic or columnar structure of the B horizon and the occurrence of visible salts at depth (although some of the sodic weathered bedrocks may not exhibit visible salts). The key to identification of a frozen Chernozemic soil with a saline subsoil is the bright coloured B horizon and the occurrence of visible salts at depth. Examples of Chernozemic soils with saline subsoils include saline Angus Ridge and saline Elnora soil series. These soils have a normal Chernozemic B horizon but salts are visible in the C horizon.

Identification and differentiation of the two types of soils is very important because they have different implications in materials handling. The Solonetzic soils are not normally subjected to a three-lift soil handling procedure but the Chernozemic soils, with a saline C horizon, may be subjected to a three-lift soil handling procedure.

If salts are encountered at depth or if a Solonetzic soil is suspected, the major horizons should be sampled for laboratory analysis.

5.5 IDENTIFICATION OF GRAVELS AND/OR SANDS

Coarse textured soils seldom freeze to a significant depth because they lack moisture. Identification of gravel or sand near the surface or at depth is not a problem during the winter because these materials are rarely frozen. The rotating auger method has to be used when gravels are encountered because the core-barrel cannot penetrate through gravel. The depth at which the sands or gravels are encountered can be accurately determined with the drill.

5.6 IDENTIFICATION OF PARENT MATERIALS

Identification of parent materials is no more a problem under winter conditions than under summer conditions. Stones in the till material are visible and stratification in lacustrine material is still evident. Identification of some of the weathered bedrock materials can be difficult in both winter and summer.

5.7 IDENTIFICATION OF GLEYSOLS

Poorly drained soils (Gleysols) can be identified even when the soils are frozen to considerable depth. Gleysols are wet soils and the frost generally penetrates to greater depths than in the adjacent, better drained upland soils. The presence of mottles and dull colours are the key to identifying Gleysols. Mottles are visible when the soils are frozen. Topsoil can easily be distinguished from subsoil by colour. Topsoil is dark coloured (black) while subsoil is dull coloured (grey). These soils are readily accessible in winter when the soils are frozen, while in summer excess moisture may prevent or hinder access and soil inspections.

5.8 IDENTIFICATION OF SURFACE STONINESS AND PRESENT LAND USE

Surface stoniness and land use are surface features which can be blanketed by a considerable depth of snow. Present land use categories commonly used are: cultivated, hay, pasture and forest. These categories can be easily identified by removing the snow from a

small area and observing the surface. The surface stoniness class is more difficult to obtain when a blanket of snow covers the surface. It often has to be inferred from the inspection site. The presence or absence of stone piles in cleared fields can be a clue to the relative stoniness class that may be expected. Surface stoniness can also be difficult to estimate under summer conditions if the area is covered by crop or forest.

5.9 MAPPING

Some soil specialists express concern about the ability to map soils under winter conditions, while others believe that soil mapping along a transect can be done just as effectively in winter as summer, and the reliability of the mapping is highly dependent on the experience of the pedologist. It should be remembered that a soil evaluation for a regulated pipeline simply involves soil inspections along a transect across the landscape. One is simply mapping along the transect, which varies from 15 to 30 m in width. Mapping is not on a quarter section, section or township basis. Inspection sites are made along a line of traverse and with the aid of aerial photographs, photomosaic alignment sheets, and topographic features identified in the field, soils with similar characteristics on similar landscapes are outlined to form a Map Unit. The number of inspection sites along a line of traverse depends on the complexity of soils and the confidence of the pedologist. Landscape features are obvious in the field, even under a blanket of snow, and can be accurately delineated on the alignment sheets. Landscape features can also be viewed stereoscopically on aerial photographs.

In the winter the crop/vegetation is not obvious if the landscape is covered with a blanket of snow. The vegetation can sometimes be used to indicate soil conditions and can be a valuable tool in identifying problem soils, especially on "looping pipelines" where a pipeline was constructed a few years ago. However, crop/vegetation information is not available to the pedologist in early spring or late fall either.

There is no question that a winter soil evaluation is carried out under less than ideal environmental conditions, but since one is

concerned with mapping only a narrow transect across the landscape, there is very good control on soil characteristics and landscape features along the transect. Mapping and identifying horizons, texture, structure, classification, etc., are different tasks that are combined for the final product. Mapping is an art and its accuracy is linked to the ability of the pedologist carrying out the soil evaluation, regardless of summer or winter conditions.

5.10 WEATHER CONDITIONS

A soil evaluation should not be conducted during a snow storm or when extremely cold temperatures occur. Drill trucks have difficulty operating when temperatures are below -20°C. Blowing snow makes it extremely difficult to: identify colours, differentiate topsoils from subsoils, and identify horizons and depth of horizons.

In early spring a situation arises where the soils begin to thaw at the surface during the day. Because the surface material is very wet and the material below is frozen, very slippery conditions occur and rutting is prominent in the surface material. If this situation arises the soil evaluation has to be temporarily suspended and may have to be confined to the morning when the surface material is still frozen. Morning light conditions in early spring are better than morning light conditions in winter, and therefore, obtaining colours of horizons should not be a problem.

5.11 CHECKING THE WINTER SOIL EVALUATION

Alberta Environment staff of the Land Conservation and Reclamation Council expressed some concern about the reduced likelihood of Reclamation Officers field checking the soil evaluation if winter conditions exist. Checking would require a drill truck which is not readily available to the Department. We suggest that if there is a concern regarding the validity of the soil evaluation it should be discussed with the project proponent and pedologist who carried out the evaluation. If disagreement still occurs after these discussions, the pedologist, the project proponent, and the Reclamation Officer should be prepared to go to the field together, to check out disagreements.

5.12 EXPERIENCE OF PEDOLOGIST

In our discussions with various people this appears to be the subject of most concern. A number of people have expressed reservations about the ability of some pedologists to map and classify soils when conditions are less than ideal. There is no question that the experience of the pedologist and familiarity with the soils and terrain in the general area are beneficial in carrying out a soil evaluation. In some regions the soils are relatively uniform and easy to classify and identify, while in other regions the soils are complex and difficult to classify and identify, even under ideal summer conditions.

Very experienced pedologists should be used in complex soil areas and areas that are difficult to map, while it may not be as critical in areas of uniform soils that are easily identified and mapped. Industry must understand that it is in their best interest to hire qualified pedologists because industry is responsible for providing sufficient and adequate soils information in the D & R Application.

An experienced, qualified pedologist is a professional agrologist who specializes in classification and mapping of soils and has a minimum of five years of soil mapping experience. Soils should be correlated with the Soil Names File of Alberta Soil Survey.

6. ADVANTAGES OF WINTER SOIL EVALUATIONS

In the previous section a number of specific concerns regarding winter soil evaluations were discussed. Other professionals often cite the disadvantages of carrying out winter soil evaluations as opposed to summer soil evaluations, but it should be pointed out that there are also some distinct advantages in carrying out winter soil evaluations with a drill truck. Some of the more obvious advantages are discussed below.

1. Poorly drained areas are readily accessible in the winter and the soil can be easily inspected. In the summer excess moisture conditions may curtail access and prevent soil inspections.
2. When using a drill truck, inspection sites are consistently examined to trench depth while in summer, when a hand auger is used, and the soils are very stony or tough, some of the inspection sites may not be to trench depth because of the difficulty in hand augering. Therefore, the lower subsoils are inspected more frequently in winter than summer and the lower subsoil characteristics are more fully documented in the report.
3. There is a tendency to sample more frequently in winter than summer, therefore more laboratory data are presented in the report. Material handling decisions are frequently based on laboratory data.
4. Frozen conditions and the lack of a crop allow for better and easier access, although deep snow may hamper progress.
5. The frozen soil is not impacted by vehicle traffic, while in summer, rutting and compaction may occur if the soil is moist.
6. Gravelly and stony areas can be readily inspected to trench depth when using a drill truck but hand augering through gravel and very stony soils is usually impossible.

7. DEGREE OF DIFFICULTY IN CONDUCTING WINTER SOIL EVALUATIONS WITHIN THE PROVINCE

There are specific regions in the province where soil evaluations in the winter (or summer) are considered relatively easy, while in other areas they may be very difficult due to the nature or complexity of the soils. Four relative rating classes are recognized and delineated in the province as having Severe, High, Moderate or Slight degrees of difficulty for winter (or summer) soil evaluations (Figure 4). Degree of difficulty classes are based on the presence or absence of salt-affected soils, but also consider parent material, colour change between topsoil and subsoil, and the complexity of soils in a specific region. The four classes of difficulty are discussed below.

7.1 SLIGHT

The majority of the Province is rated as having a Slight degree of difficulty for winter (or summer) soil evaluations. Areas with Slight degree include: Gray Luvisolic soils with little or no topsoil (Ah or Ahe horizons) in forested areas, and the Black Chernozemic soils near Calgary, Edmonton and Lloydminster. Salt-affected soils are rare and topsoils, if they occur, can generally be distinguished from subsoils by colour. Deep snow, poor light and short days are limitations in the northern portion of the province.

7.2 MODERATE

The portion of the Dark Brown Soil Zone that does not have salt-affected soils is rated as having a Moderate degree of difficulty for winter (or summer) soil evaluations. Some problems may occur in distinguishing topsoil from subsoil by colour.

7.3 HIGH

Areas with a High degree of difficulty for winter (or summer) soil evaluations include: salt-affected soils in the Peace River Region; salt-affected soils in the Westlock, Edmonton, Camrose and Lloydminster areas; and, soils in the Brown Soil Zone that are not salt-affected.

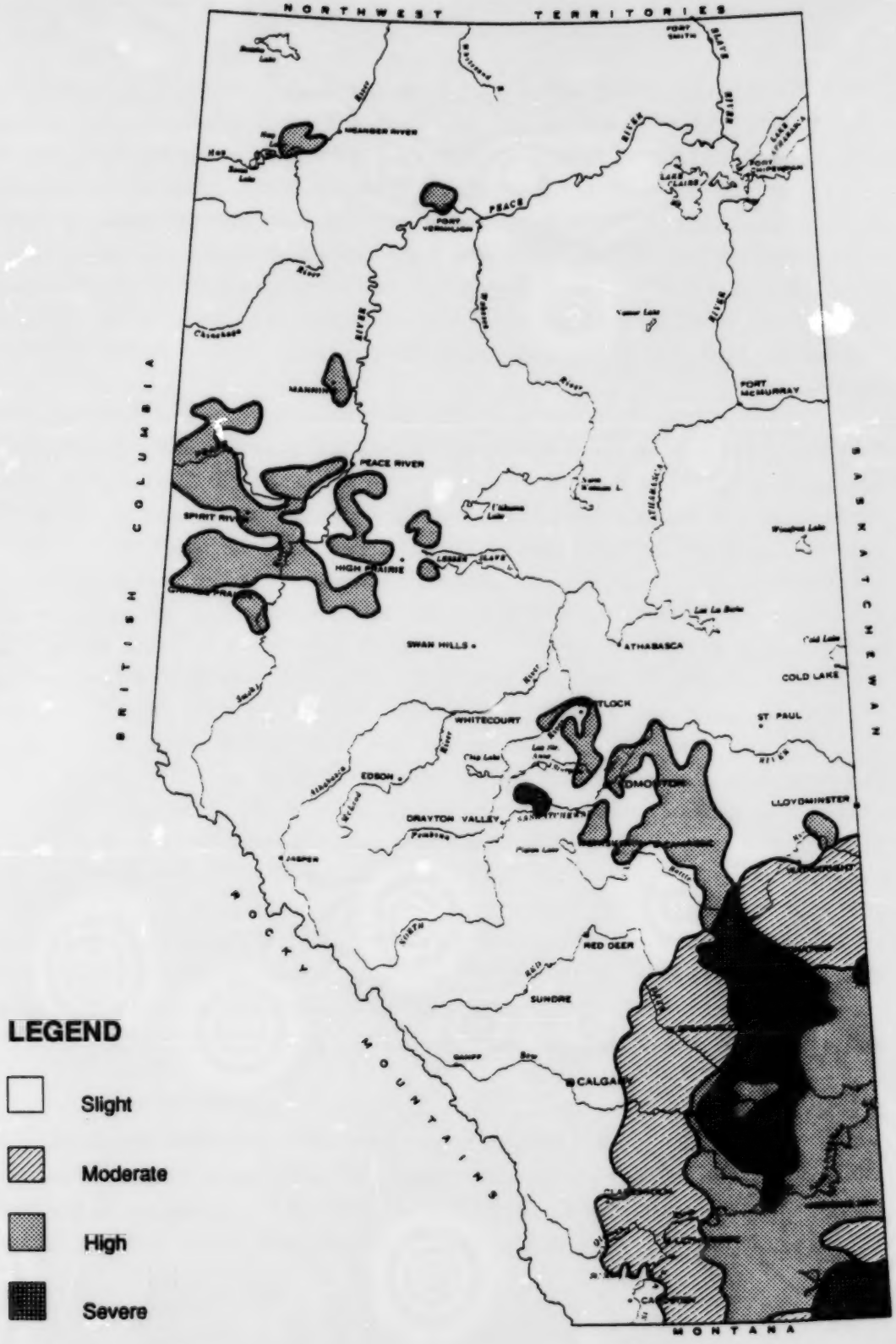

Figure 4. Degree of Difficulty in Conducting Winter Soil Evaluations in Alberta.

Salt-affected soils in the Peace River Region are generally clay loam to clay textured and are developed on dark coloured parent materials. Colour differentiation of topsoil from subsoil may be poor and it may be difficult to identify a Bnt horizon because of the strong structures, dark colours, and high clay content in the upper subsoil and parent material. Many of the salt-affected soils in the Peace River Region have a very low content of soluble salts at depth and salts are not always visible in the Csk horizon. Deep snow, poor light and short days are other important limitations in the Peace River Region.

Salt-affected soils in the Westlock, Edmonton, Camrose and Lloydminister areas have different kinds of limitations for winter soil evaluations than those occurring in the Peace River Region. Parent materials are not as dark coloured and usually not as fine textured. Colour differentiation between topsoil and subsoil may not be obvious but topsoil can sometimes be distinguished from subsoil by texture or structure. Topsoils have a granular structure while the Solonetzic B horizon has strong columnar or prismatic structure. Frequently a thin, lighter coloured Ae horizon occurs between the topsoil and subsoil. The Csk horizon has a high content of salts that are usually visible.

The non-saline Brown soils occur in the southern portion of the Province and are rated as having a High degree of difficulty for winter (or summer) soil evaluations because of poor colour change between topsoil and subsoil (both the topsoil and subsoil can be brown). However, soils in the Brown Soil Zone seldom freeze below the 20 to 25 cm depth, and light conditions are better and days longer than in the northern portion of the province. Since frost penetration is shallow, a core-barrel can often be used rather than a rotating auger, to excavate the soil for inspection. Snow drifts may restrict access and it may be necessary to have the route snow plowed.

7.4 SEVERE

The salt-affected soils in the Brown and Dark Brown Soil Zones are considered to have a Severe degree of difficulty for winter (or summer) soil evaluations. Topsoils are not easily distinguished from subsoils by colour, and saline/sodic conditions occur sporadically

throughout the region. The area near the south shore of Wabamun Lake near the City of Edmonton is also rated as having a Severe degree of difficulty because of the complexity of soil and parent materials in the region. A complex association of Solonetzic, Chernozemic, Luvisolic, and Gleysolic soils developed on weathered bedrock, till, glaciolacustrine, glaciofluvial, and eolian deposits occur in the region.

8. DISCUSSION

A soil evaluation is conducted to provide information about the soils and landforms along a proposed pipeline to assist in soil conservation planning for pipeline construction. Although a winter soil evaluation may be conducted under less than ideal environmental conditions, and the information gathered may not be as detailed or accurate as one would obtain under summer conditions, the information obtained from a winter soil evaluation generally has sufficient content and accuracy to meet the objective.

Taxonomic classification of the soil in some cases is not required. The most important parameters are topsoil depth, topsoil-subsoil colour change, changes in salinity and sodicity with depth, and the occurrence of sands, gravels or bedrock (undesirable materials) at depth. Some of these parameters are only determined after sampling and laboratory analysis. More sampling and laboratory analysis may be required in specific areas under winter conditions than summer conditions. Other parameters can only be investigated thoroughly with a drill truck (sands, gravel or bedrock at depth).

What are the consequences for planning and material handling procedures if the structure, consistence or even topsoil depth are not accurately described or delineated? Topsoil depth and even colour can sometimes change drastically over a very short distance; depth to gravel or saline and sodic material can fluctuate greatly over a short distance; and present land use or management can influence topsoil quality, colour, and depth. The topsoil depth indicated in a Map Unit on the alignment sheet expresses the average topsoil depth, rounded off to the nearest 5 cm increment in a specific area. This does not mean that topsoil depth cannot fluctuate greatly from the average, nor does it mean that the colour change of the topsoil from subsoil is consistent.

Soil conditions at the time of the soil evaluation are extremely important. Few problems are encountered if the soils are not frozen below the topsoil horizon.

The experience of pedologists and familiarity with the soils in a specific area is also important, especially in areas of complex soils that are difficult to map. A greater number of inspection sites

and sampling sites is required in complex soil areas as well as in areas of salt-affected soils.

The ease and accuracy of a soil evaluation in a specific area is not entirely dependent on the season. Specific areas that are difficult to map in the winter are also often difficult to map in the summer. However, because less than ideal conditions occur with a winter soil evaluation, a higher site inspection and sampling density should be carried out in areas of Severe and High degrees of difficulty. Ultimately the decision in inspection and sampling density in a specific area has to be left with the pedologist in the field. He or she has to feel confident that sufficient and adequate soils information has been provided to assist in soil conservation planning for pipeline construction along the right of way. Government reviewers also need the same level of confidence.

The amount and type of existing soils information in a specific area can also affect site inspection and sampling density. For example, a soil evaluation conducted within a kilometre of a prior soil evaluation for a pipeline project will probably have a great deal of information that is pertinent to the present study, and the site inspection and sampling density can be reduced significantly.

9. CONCLUSIONS

A soil evaluation is required in support of a D & R Application where arable land, potentially arable land or pasture land is to be disturbed. The objective of the soil evaluation is to provide information about the soils and landforms along a proposed pipeline. The information is used for soil conservation planning for pipeline construction. There is considerable preference for summer soil evaluations over winter soil evaluations by all parties concerned. **If possible, soil evaluations should be carried out under summer conditions**. If this is not possible, evaluations can be carried out under less than ideal winter conditions with a high degree of reliability, but a greater amount of time and effort is required in the field by the pedologist.

Soil inspections during the winter should be done with a drill truck that is capable of coring and/or augering to trench depth. Since a core causes less disturbance to the soil profile the core method is preferred over the rotating auger method. It should be remembered that the soils seldom freeze below 70 cm and generally freeze only to the 50 cm depth. A winter soil evaluation generally means a reduced working day because of the occurrence of poor light in the early morning and late afternoon. There may or may not be other serious constraints, such as deep snow, in performing winter soil evaluations.

Some regions in the province are considered to have a Severe degree of difficulty for winter (or summer) soil evaluations while other regions are considered to have a Slight degree of difficulty for winter (or summer) soil evaluations. Soils that are difficult to recognize and map in the winter are also frequently difficult to recognize and map in the summer. Some specific soil parameters may be difficult to measure or determine during winter soil evaluations and the site inspection and sampling density may have to be increased by as much as 50 percent. The depth of frost penetration, the type of soils that are likely to be encountered, the experience of the pedologist, the amount and type of soils information already available, and the general region of the soil evaluation are factors that have to be seriously considered prior to initiation of the evaluation.

Areas of salt-affected soils are of prime concern. These soils are easily recognized when only the topsoil is frozen but may be difficult to recognize if frost has penetrated into the subsoil. These soils are confined to specific areas within the province. If the soil cannot be inspected by extracting a core and the rotating auger method has to be used, the soil should be sampled 50 percent more frequently than would occur under summer conditions.

It should be noted that some soil parameters that are recognized in a general purpose soil survey are not relevant in soil evaluations for pipelines. For instance, various taxonomic distinctions are not necessary in many of the soils but are important in the salt-affected soils. Topsoil depth, present land use, and the characteristics and quality of the topsoil and upper and lower subsoils are important parameters that have to be documented.

Although winter soil evaluations are sometimes carried out under less than ideal conditions and there may be some disadvantages to this, there are also distinct advantages in using a drill truck for soil inspections during the winter. Wet areas are easily accessible when frozen; the soils are consistently inspected to trench depth; a frozen soil is not impacted by vehicle traffic; and, stony or gravelly soils can be inspected with little or no difficulty.

10. RECOMMENDATIONS

Based on personal experience and discussions with various individuals, the following recommendations are put forth.

1. If possible, soil evaluations should be scheduled to be carried out under non-frozen summer conditions.
2. If a winter soil evaluation is necessary, the soil evaluation can be conducted during the winter with a high degree of reliability, but a greater amount of time and effort is required in the field by the pedologist.
3. Regardless of summer or winter conditions, it is recommended that the site inspection and sampling density be increased by about 50 percent above the normal in areas of "Severe" and "High" degrees of difficulty as shown in Figure 4. Ultimately, the decision regarding inspection and sampling density in a specific area has to be left with the pedologist in the field, but all parties must feel confident that a sufficient and adequate inventory of the soil resources has been undertaken.
4. For any soil evaluation, the pedologist should make use of:
    a. Reconnaissance soil survey reports;
    b. County soil survey reports;
    c. Pipeline soil evaluation reports;
    d. Alberta Soil Survey contacts.
5. In addition, the pedologist needs to:
    a. Get a general idea of conditions in the project area at the time of the evaluation. If it's too wet, the survey may need to be delayed until later in the summer. If there's snow, the proposed route may need to be plowed;
    b. Decide the type and capability of equipment necessary for the site inspections;
    c. Determine the probability of encountering salt-affected soils along the proposed route. If salt-affected soils are prominent, a higher site

inspection and sampling density will likely be required;

d. Determine if specific guidelines are required for the project and initiate appropriate discussions with the proponent.

6. Over the years there has been a vast amount of soils information gathered from previous regulated pipeline studies in Alberta. This information resides in the library of the Development and Reclamation Branch of Alberta Environment. This soils information is not readily accessible or available to the general public. It is recommended that the library be organized (computerized) so that the soils information from previous studies is easily searched, and is more available to all personnel concerned.

11. REFERENCES CITED

Alberta Environment, 1988. Information Requirements for Regulated Pipelines. Alberta Environment, Land Reclamation Division, Edmonton, Alberta. 38 pp.

12. APPENDICES

12.1 LIST OF DISCUSSION GROUPS AND PERSONNEL

During the course of the study discussions were held with the following individuals.

1. Alberta Soil Survey
   - B. Howitt
   - G. Coen
   - B. Walker
   - T. Brierly
   - T. Macyk

2. Alberta Agriculture
   - J. Hermans
   - L. Marciak

3. Alberta Environment
   - L. Brocke
   - A. Janz
   - T. Ferguson
   - H. Slavinsky

4. Alberta Forestry, Lands and Wildlife
   - W. Tedder

5. Soil Consultants
   - D. James
   - K. Bessie
   - L. Leskiw
   - L. Knapik
   - N. Finlayson
   - C. Heath

6. Oil and Gas Industry
   - F. Kuipers
   - I. Scott
   - B. Seager
   - L. Postlewaite
   - R. Staniland
   - D. McCoy
   - G. Mott
   - C. Cloutier

7. Soil Drilling Contractors
   - D. Norrie
   - P. Gerwing

RECLAMATION RESEARCH REPORTS

1. **RRTAC 79-2: Proceedings: Workshop on Native Shrubs in Reclamation. P.F. Ziemkiewicz, C.A. Dermott and H.P. Sims (Editors). 104 pp. No longer available.**

The Workshop was organized as the first step in developing a Native Shrub reclamation research program. The Workshop provided a forum for the exchange of information and experiences on three topics: propagation; outplanting; and, species selection. Seven papers and the results of three discussion groups are presented.

2. **RRTAC 80-1: Test Plot Establishment: Native Grasses for Reclamation. R.S. Sadasivaiah and J. Weijer. 19 pp. No longer available.**

The report details the species used at three test plots in Alberta's Eastern Slopes (one at Caw Creek Ridge and two at Cadomin). Site preparation, experimental design, and planting method are also described.

3. **RRTAC 80-3: The Role of Organic Compounds in Salinization of Plains Coal Mining Sites. N.S.C. Cameron et al. 46 pp. $10.00**

This is a literature review of the chemistry of sodic mine spoil and the changes expected to occur in groundwater.

4. **RRTAC 80-4: Proceedings: Workshop on Reconstruction of Forest Soils in Reclamation. P.F. Ziemkiewicz, S.K. Takyi and H.F. Regier (Editors). 160 pp. $10.00**

Experts in the field of forestry and forest soils report on research relevant to forest soil reconstruction and discuss the most effective means of restoring forestry capability of mined lands.

5. **RRTAC 80-5: Manual of Plant Species Suitability for Reclamation in Alberta. L.E. Watson, R.W. Parker and D.F. Polster. 2 vols, 541 pp. No longer available; replaced by RRTAC 89-4.**

Forty-three grass, fourteen forb, and thirty-four shrub and tree species are assessed in terms of their suitability for use in reclamation. Range maps, growth habit, propagation, tolerance, and availability information are provided.

6. **RRTAC 81-2: 1980 Survey of Reclamation Activities in Alberta. D.G. Walker and R.L. Rothwell. 76 pp. $10.00**

This survey is an update of a report prepared in 1976 on reclamation activities in Alberta, and includes research and operational reclamation, locations, personnel, etc.

7. **RRTAC 81-3: Proceedings: Workshop on Coal Ash and Reclamation. P.F. Ziemkiewicz, R. Stein, R. Leitch and G. Lutwick (Editors). 253 pp. $10.00**

Presents nine technical papers on the chemical, physical, and engineering properties of Alberta fly and bottom ashes, revegetation of ash disposal sites, and use of ash as a soil amendment. Workshop discussions and summaries are also included.

8. **RRTAC 82-1: Land Surface Reclamation: An International Bibliography. H.P. Sims and C.B. Powter. 2 vols, 292 pp. $10.00**

Literature to 1980 pertinent to reclamation in Alberta is listed in Vol. 1 and is also on the University of Alberta computing system (in a SPIRES database called RECLAIM). Vol. 2 comprises the keyword index and computer access manual.

9. **RRTAC 82-2: A Bibliography of Baseline Studies in Alberta: Soils, Geology, Hydrology and Groundwater. C.B. Powter and H.P. Sims. 97 pp. $5.00**

This bibliography provides baseline information for persons involved in reclamation research or in the preparation of environmental impact assessments. Materials, up to date as of December 1981, are available in the Alberta Environment Library.

10. **RRTAC 83-1: Soil Reconstruction Design for Reclamation of Oil Sand Tailings. Monenco Consultants Ltd. 185 pp. No longer available**

Volumes of peat and clay required to amend oil sand tailings were estimated based on existing literature. Separate soil prescriptions were made for spruce, jack pine, and herbaceous cover types. The estimates form the basis of field trials.

11. **RRTAC 83-3: Evaluation of Pipeline Reclamation Practices on Agricultural Lands in Alberta. Hardy Associates (1978) Ltd. 205 pp. No longer available.**

Available information on pipeline reclamation practices was reviewed. A field survey was then conducted to determine the effects of pipe size, age, soil type, construction method, etc. on resulting crop production.

12. **RRTAC 83-4: Proceedings: Effects of Coal Mining on Eastern Slopes Hydrology. P.F. Ziemkiewicz (Editor). 123 pp. $10.00**

Technical papers are presented dealing with the impacts of mining on mountain watersheds, their flow characteristics, and resulting water quality. Mitigative measures and priorities were also discussed.

13. **RRTAC 83-5: Woody Plant Establishment and Management for Oil Sands Mine Reclamation. Techman Engineering Ltd. 124 pp. No longer available.**

This is a review and analysis of information on planting stock quality, rearing techniques, site preparation, planting, and procedures necessary to ensure survival of trees and shrubs in oil sand reclamation.

14. **RRTAC 84-1: Land Surface Reclamation: A Review of the International Literature. H.P. Sims, C.B. Powter and J.A. Campbell. 2 vols, 1549 pp. $20.00**

Nearly all topics of interest to reclamationists including mining methods, soil amendments, revegetation, propagation and toxic materials are reviewed in light of the international literature.

15. **RRTAC 84-2: Propagation Study: Use of Trees and Shrubs for Oil Sand Reclamation. Techman Engineering Ltd. 58 pp. $10.00**

This report evaluates and summarizes all available published and unpublished information on large-scale propagation methods for shrubs and trees to be used in oil sand reclamation.

16. **RRTAC 84-3: Reclamation Research Annual Report - 1983. P.F. Ziemkiewicz. 42 pp. $5.00**

This report details the Reclamation Research Program indicating priorities, descriptions of each research project, researchers, results, and expenditures.

17. **RRTAC 84-4: Soil Microbiology in Land Reclamation. D. Parkinson, R.M. Danielson, C. Griffiths, S. Visser and J.C. Zak. 2 vols, 676 pp. $10.00**

This is a collection of five reports dealing with re-establishment of fungal decomposers and mycorrhizal symbionts in various amended spoil types.

18. **RRTAC 85-1: Proceedings: Revegetation Methods for Alberta's Mountains and Foothills. P.F. Ziemkiewicz (Editor). 416 pp. $10.00**

Results of long-term experiments and field experience on species selection, fertilization, reforestation, topsoiling, shrub propagation and establishment are presented.

19. **RRTAC 85-2: Reclamation Research Annual Report - 1984. P.F. Ziemkiewicz. 29 pp. $5.00**

This report details the Reclamation Research Program indicating priorities, descriptions of each research project, researchers, results, and expenditures.

20. **RRTAC 86-1: A Critical Analysis of Settling Pond Design and Alternative Technologies. A. Somani. 372 pp. $10.00**

The report examines the critical issue of settling pond design, and sizing and alternative technologies. The study was co-funded with The Coal Association of Canada.

21. **RRTAC 86-2: Characterization and Variability of Soil Reconstructed after Surface Mining in Central Alberta. T.M. Macyk. 146 pp. No longer available.**

Reconstructed soils representing different materials handling and replacement techniques were characterized, and variability in chemical and physical properties was assessed. The data obtained indicate that reconstructed soil properties are determined largely by parent material characteristics and further tempered by materials handling procedures. Mining tends to create a relatively homogeneous soil landscape in contrast to the mixture of diverse soils found before mining.

22. **RRTAC 86-3: Generalized Procedures for Assessing Post-Mining Groundwater Supply Potential in the Plains of Alberta - Plains Hydrology and Reclamation Project. M.R. Trudell and S.R. Moran. 30 pp. $5.00**

In the Plains region of Alberta, the surface mining of coal generally occurs in rural, agricultural areas in which domestic water supply requirements are met almost entirely by groundwater. Consequently, an important aspect of the capability of reclaimed lands to satisfy the needs of a residential component is the post-mining availability of groundwater. This report proposes a sequence of steps or procedures to identify and characterize potential post-mining aquifers.

23. **RRTAC 86-4: Geology of the Battle River Site: Plains Hydrology and Reclamation Project. A. Maslowski-Schutze, R. Li, M. Fenton and S.R. Moran. 86 pp. $10.00**

This report summarizes the geological setting of the Battle River study site. It is designed to provide a general understanding of geological conditions adequate to establish a framework for hydrogeological and general reclamation studies. The report is not intended to be a detailed synthesis such as would be required for mine planning purposes.

24. **RRTAC 86-5: Chemical and Mineralogical Properties of Overburden: Plains Hydrology and Reclamation Project. A. Maslowski-Schutze. 71 pp. $10.00**

This report describes the physical and mineralogical properties of overburden materials in an effort to identify individual beds within the bedrock overburden that might be significantly different in terms of reclamation potential.

25. **RRTAC 86-6: Post-Mining Groundwater Supply at the Battle River Site: Plains Hydrology and Reclamation Project. M.R. Trudell, G.J. Sterenberg and S.R. Moran. 49 pp. $5.00**

The report deals with the availability of water supply in or beneath cast overburden to support post-mining land use, including both quantity and quality considerations. The study area is in the Battle River Mining area in east-central Alberta.

26. **RRTAC 86-7: Post-Mining Groundwater Supply at the Highvale Site: Plains Hydrology and Reclamation Project. M.R. Trudell. 25 pp. $5.00**

This report evaluates the availability of water supply in or beneath cast overburden to support post-mining land use, including both quantity and quality considerations. The study area is the Highvale mining area in west-central Alberta.

27. **RRTAC 86-8: Reclamation Research Annual Report - 1985. P.F. Ziemkiewicz. 54 pp. $5.00**

This report details the Reclamation Research Program indicating priorities, descriptions of each research project, researchers, results, and expenditures.

28. **RRTAC 86-9: Wildlife Habitat Requirements and Reclamation Techniques for the Mountains and Foothills of Alberta. J.E. Green, R.E. Salter and D.G. Walker. 285 pp. No longer available.**

This report presents a review of relevant North American literature on wildlife habitats in mountain and foothills biomes, reclamation techniques, potential problems in wildlife habitat reclamation, and potential habitat assessment methodologies. Four biomes (Alpine, Subalpine, Montane, and Boreal Uplands) and 10 key wildlife species (snowshoe hare, beaver, muskrat, elk, moose, caribou, mountain goat, bighorn sheep, spruce grouse, and white-tailed ptarmigan) are discussed. The study was co-funded with The Coal Association of Canada.

29. **RRTAC 87-1: Disposal of Drilling Wastes. L.A. Leskiw, E. Reinl-Dwyer, T.L. Dabrowski, B.J. Rutherford and H. Hamilton. 210 pp. No longer available.**

Current drilling waste disposal practices are reviewed and criteria in Alberta guidelines are assessed. The report also identifies research needs and indicates mitigation measures. A manual provides a decision-making flowchart to assist in selecting methods of environmentally safe waste disposal.

30. **RRTAC 87-2: Minesoil and Landscape Reclamation of the Coal Mines in Alberta's Mountains and Foothills. A.W. Fedkenheuer, L.J. Knapik and D.G. Walker. 174 pp. No longer available.**

This report reviews current reclamation practices with regard to site and soil reconstruction and re-establishment of biological productivity. It also identifies research needs in the Mountain-Foothills area. The study was co-funded with The Coal Association of Canada.

31. **RRTAC 87-3: Gel and Saline Drilling Wastes in Alberta: Workshop Proceedings. D.A. Lloyd (Compiler). 218 pp. No longer available.**

Technical papers were presented which describe: mud systems used and their purpose; industrial constraints; government regulations, procedures and concerns; environmental considerations in waste disposal; and toxic constituents of drilling wastes. Answers to a questionnaire distributed to participants are included in an appendix.

32. **RRTAC 87-4: Reclamation Research Annual Report - 1986. 50 pp. No longer available.**

This report details the Reclamation Research Program indicating priorities, descriptions of each research project, researchers, results, and expenditures.

33. **RRTAC 87-5: Review of the Scientific Basis of Water Quality Criteria for the East Slope Foothills of Alberta. Beak Associates Consulting Ltd. 46 pp. $10.00**

The report reviews existing Alberta guidelines to assess the quality of water drained from coal mine sites in the East Slope Foothills of Alberta. World literature was reviewed within the context of the East Slopes environment and current mining operations. The ability of coal mine operators to meet the various guidelines is discussed. The study was co-funded with The Coal Association of Canada.

34. **RRTAC 87-6: Assessing Design Flows and Sediment Discharge on the Eastern Slopes. Hydrocon Engineering (Continental) Ltd. and Monenco Consultants Ltd. 97 pp. $10.00**

The report provides an evaluation of current methodologies used to determine sediment yields due to rainfall events in well-defined areas. Models are available in Alberta to evaluate water and sediment discharge in a post-mining situation. SEDIMOT II (Sedimentology Disturbed Modelling Techniques) is a single storm model that was developed specifically for the design of sediment control structures in watersheds disturbed by surface mining and is well suited to Alberta conditions. The study was co-funded with The Coal Association of Canada.

35. **RRTAC 87-7: The Use of Bottom Ash as an Amendment to Sodic Spoil. S. Fullerton. 83 pp. No longer available.**

The report details the use of bottom ash as an amendment to sodic coal mine spoil. Several rates and methods of application of bottom ash to sodic spoil were tested to determine which was the best at reducing the effects of excess sodium and promoting crop growth. Field trials were set up near the Vesta mine in East Central Alberta using ash readily available from a nearby coal-fired thermal generating station. The research indicated that bottom ash incorporated to a depth of 30 cm using a subsoiler provided the best results.

36. **RRTAC 87-8: Waste Dump Design for Erosion Control. R.G. Chopiuk and S.E. Thornton. 45 pp. $5.00**

This report describes a study to evaluate the potential influence of erosion from reclaimed waste dumps on downslope environments such as streams and rivers. Sites were selected from coal mines in Alberta's mountains and foothills, and included resloped dumps of different configurations and ages, and having different vegetation covers. The study concluded that the average annual amount of surface erosion is minimal. As expected, erosion was greatest on slopes which were newly regraded. Slopes with dense grass cover showed no signs of erosion. Generally, the amount of erosion decreased with time, as a result of initial loss of fine particles, the formation of a weathered surface, and increased vegetative cover.

37. **RRTAC 87-9: Hydrogeology and Groundwater Chemistry of the Battle River Mining Area. M.R. Trudell, R.L. Faught and S.R. Moran. 97 pp. No longer available.**

This report describes the premining geologic conditions in the Battle River coal mining area including the geology as well as the groundwater flow patterns, and the groundwater quality of a sequence of several water-bearing formations extending from the surface to a depth of about 100 metres.

38. **RRTAC 87-10: Soil Survey of the Plains Hydrology and Reclamation Project - Battle River Project Area. T.M. Macyk and A.H. MacLean. 62 pp. plus 8 maps. $10.00**

The report evaluates the capability of post-mining landscapes and assesses the changes in capability as a result of mining, in the Battle River mining area. Detailed soils information is provided in the report for lands adjacent to areas already mined as well as for lands that are destined to be mined. Characterization of the reconstructed soils in the reclaimed areas is also provided. Data were collected from 1979 to 1985. Eight maps supplement the report.

39. **RRTAC 87-11: Geology of the Highvale Study Site: Plains Hydrology and Reclamation Project. A. Maslowski-Schutze. 78 pp. $10.00**

The report is one of a series that describes the geology, soils and groundwater conditions at the Highvale Coal Mine study site. The purpose of the study was to establish a summary of site geology to a level of detail necessary to provide a framework for studies of hydrogeology and reclamation.

40. **RRTAC 87-12: Premining Groundwater Conditions at the Highvale Site. M.R. Trudell and R. Faught. 83 pp. $10.00**

This report presents a detailed discussion of the premining flow patterns, hydraulic properties, and isotopic and hydrochemical characteristics of five layers within the Paskapoo Geological Formation, the underlying sandstone beds of the Upper Horseshoe Canyon Formation, and the surficial glacial drift.

41. **RRTAC 87-13: An Agricultural Capability Rating System for Reconstructed Soils. T.M. Macyk. 27 pp. $5.00**

This report provides the rationale and a system for assessing the agricultural capability of reconstructed soils. Data on the properties of the soils used in this report are provided in RRTAC 86-2.

42. **RRTAC 88-1: A Proposed Evaluation System for Wildlife Habitat Reclamation in the Mountains and Foothills Biomes of Alberta: Proposed Methodology and Assessment Handbook. T.R. Eccles, R.E. Salter and J.E. Green. 101 pp. plus appendix. $10.00**

The report focuses on the development of guidelines and procedures for the assessment of reclaimed wildlife habitat in the Mountains and Foothills regions of Alberta. The technical section provides background documentation including a discussion of reclamation planning, a listing of reclamation habitats and associated key wildlife species, conditions required for development, recommended revegetation species, suitable reclamation techniques, a description of the recommended assessment techniques and a glossary of basic terminology. The assessment handbook section contains basic information necessary for evaluating wildlife habitat reclamation, including assessment scoresheets for 15 different reclamation habitats, standard methodologies for measuring habitat variables used as assessment criteria, and minimum requirements for certification. This handbook is intended as a field manual that could potentially be used by site operators and reclamation officers. The study was co-funded with The Coal Association of Canada.

43. **RRTAC 88-2: Plains Hydrology and Reclamation Project: Spoil Groundwater Chemistry and its Impacts on Surface Water. M.R. Trudell (Compiler). 135 pp. $10.00**

Two reports comprise this volume. The first "Chemistry of Groundwater in Mine Spoil, Central Alberta," describes the chemical make-up of spoil groundwater at four mines in the Plains of Alberta. It explains the nature and magnitude of changes in groundwater chemistry following mining and reclamation. The second report, "Impacts of Surface Mining on Chemical Quality of Streams in the Battle River Mining Area," describes the chemical quality of water in streams in the Battle River mining area, and the potential impact of groundwater discharge from surface mines on these streams.

44. **RRTAC 88-3: Revegetation of Oil Sands Tailings: Growth Improvement of Silver-berry and Buffalo-berry by Inoculation with Mycorrhizal Fungi and N_2-Fixing Bacteria. S. Visser and R.M. Danielson. 98 pp. $10.00**

The report provides results of a study: (1) To determine the mycorrhizal affinities of various actinorrhizal shrubs in the Fort McMurray, Alberta region; (2) To establish a basis for justifying symbiont inoculation of buffalo-berry and silver-berry; (3) To develop a growing regime for the greenhouse production of mycorrhizal, nodulated silver-berry and buffalo-berry; and, (4) To conduct a field trial on reconstructed soil on the Syncrude Canada Limited oil sands site to critically evaluate the growth performance of inoculated silver-berry and buffalo-berry as compared with their un-inoculated counterparts.

45. **RRTAC 88-4: Plains Hydrology and Reclamation Project: Investigation of the Settlement Behaviour of Mine Backfill. D.R. Pauls (compiler). 135 pp. $10.00**

This three part volume covers the laboratory assessment of the potential for subsidence in reclaimed landscapes. The first report in this volume, "Simulation of Mine Spoil Subsidence by Consolidation Tests," covers laboratory simulations of the subsidence process particularly as it is influenced by resaturation of mine spoil. The second report, "Water Sensitivity of Smectitic Overburden: Plains Region of Alberta," describes a series of laboratory tests to determine the behaviour of overburden materials when brought into contact with water. The report entitled "Classification System for Transitional Materials: Plains Region of Alberta," describes a lithological classification system developed to address the characteristics of the smectite rich, clayey transition materials that make up the overburden in the Plains of Alberta.

46. **RRTAC 88-5: Ectomycorrhizae of Jack Pine and Green Alder: Assessment of the Need for Inoculation, Development of Inoculation Techniques and Outplanting Trials on Oil Sand Tailings. R.M. Danielson and S. Visser. 177 pp. $10.00**

The overall objective of this research was to characterize the mycorrhizal status of Jack Pine and Green Alder which are prime candidates as reclamation species for oil sand tailings and to determine the potential benefits of mycorrhizae on plant performance. This entailed determining the symbiont status of container-grown nursery stock and the quantity and quality of inoculum in reconstructed soils, developing inoculation techniques and finally, performance testing in an actual reclamation setting.

47. **RRTAC 88-6: Reclamation Research Annual Report - 1987. Reclamation Research Technical Advisory Committee. 67 pp. No longer available.**

This annual report describes the expenditure of $500,000.00 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

48. **RRTAC 88-7: Baseline Growth Performance Levels and Assessment Procedure for Commercial Tree Species in Alberta's Mountains and Foothills. W.R. Dempster and Associates Ltd. 66 pp. $5.00**

Data on juvenile height development of lodgepole pine and white spruce from cut-over or burned sites in the Eastern Slopes of Alberta were used to define reasonable expectations of early growth performance as a basis for evaluating the success of reforestation following coal mining. Equations were developed predicting total seedling height and current annual height increment as a function of age and elevation. Procedures are described for applying the equations, with further adjustments for drainage class and aspect, to develop local growth performance against these expectations. The study was co-funded with The Coal Association of Canada.

49. **RRTAC 88-8: Alberta Forest Service Watershed Management Field and Laboratory Methods. A.M.K. Nip and R.A. Hursey. 4 Sections, various pagings. $10.00**

Disturbances such as coal mines in the Eastern Slopes of Alberta have the potential for affecting watershed quality during and following mining. The collection of hydrometric, water quality and hydrometeorologic information is a complex task. A variety of instruments and measurement methods are required to produce a record of hydrologic inputs and outputs for a watershed basin. There is a growing awareness and recognition that standardization of data acquisition methods is required to ensure data comparability, and to allow comparison of data analyses. The purpose of this manual is to assist those involved in the field of data acquisition by outlining methods, practices and instruments which are reliable and recognized by the International Organization for Standardization.

50. **RRTAC 88-9: Computer Analysis of the Factors Influencing Groundwater Flow and Mass Transport in a System Disturbed by Strip Mining. F.W. Schwartz and A.S. Crowe. 78 pp. $10.00**

Work presented in this report demonstrates how a groundwater flow model can be used to study a variety of mining-related problems such as declining water levels in areas around the mine as a result of dewatering, and the development of high water tables in spoil once resaturation is complete. This report investigates the role of various hydrogeological parameters that influence the magnitude, timing, and extent of water level changes during and following mining at the regional scale. The modelling approach described here represents a major advance on existing work.

51. **RRTAC 88-10: Review of Literature Related to Clay Liners for Sump Disposal of Drilling Wastes. D.R. Pauls, S.R. Moran and T. Macyk. 61 pp. $5.00**

The report reviews and analyses the effectiveness of geological containment of drilling waste in sumps. Of particular importance was the determination of changes in properties of clay materials as a result of contact with highly saline brines containing various organic chemicals.

52. **RRTAC 88-11: Highvale Soil Reconstruction Project: Five Year Summary. D.N. Graveland, T.A. Oddie, A.E. Osborne and L.A. Panek. 104 pp. $10.00**

This report provides details of a five year study to determine a suitable thickness of subsoil to replace over minespoil in the Highvale plains coal mine area to ensure return of agricultural capability. The study also examined the effect of slope and aspect on agricultural capability. This study was funded and managed with industry assistance.

53. **RRTAC 88-12: A Review of the International Literature on Mine Spoil Subsidence. J.D. Scott, G. Zinter, D.R. Pauls and M.B. Dusseault. 36 pp. $10.00**

The report reviews available engineering literature relative to subsidence of reclaimed mine spoil. The report covers methods for site investigation, field monitoring programs and lab programs, mechanisms of settlement, and remedial measures.

54. **RRTAC 89-1: Reclamation Research Annual Report - 1988. 74 pp. $5.00**

This annual report describes the expenditure of $280,000.00 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

55. **RRTAC 89-2: Proceedings of the Conference: Reclamation, A Global Perspective. D.G. Walker, C.B. Powter and M.W. Pole (Compilers). 2 Vols., 854 pp. $10.00**

Over 250 delegates from all over the world attended this conference held in Calgary in August, 1989. The proceedings contains over 85 peer-reviewed papers under the following headings: A Global Perspective; Northern and High Altitude Reclamation; Fish & Wildlife and Rangeland Reclamation; Water; Herbaceous Revegetation; Woody Plant Revegetation and Succession; Industrial and Urban Sites; Problems and Solutions; Sodic and Saline Materials; Soils and Overburden; Acid Generating Materials; and, Mine Tailings.

56. **RRTAC 89-3: Efficiency of Activated Charcoal for Inactivation of Bromacil and Tebuthiuron Residues in Soil. M.P. Sharma. 38 pp. $5.00**

Bromacil and Tebuthiuron were commonly used soil sterilants on well sites, battery sites and other industrial sites in Alberta where total vegetation control was desired. Activated charcoal was found to be effective in binding the sterilants in greenhouse trials. The influence of factors such as herbicide:charcoal concentration ratio, soil texture, organic matter content, soil moisture, and the time interval between charcoal incorporation and plant establishment were evaluated in the greenhouse.

57. **RRTAC 89-4: Manual of Plant Species Suitability for Reclamation in Alberta - 2nd Edition. Hardy BBT Limited. 436 pp. $10.00**

This is an updated version of RRTAC Report 80-5 which describes the characteristics of 43 grass, 14 forb and 34 shrub and tree species which make them suitable for reclamation in Alberta. The report has been updated in several important ways: a line drawing of each species has been added; the range maps for each species have been redrawn based on an ecosystem classification of the province; new information (to 1990) has been added, particularly in the sections on reclamation use; and the material has been reorganized to facilitate information retrieval. Of greatest interest is the performance chart that precedes each species and the combined performance charts for the grass, forb, and shrub/tree groups. These allow the reader to pick out at a glance species that may suit their particular needs. The report was produced with the assistance of a grant from the Recreation, Parks and Wildlife Foundation.

58. **RRTAC 89-5: Battle River Soil Reconstruction Project Five Year Summary. L.A. Leskiw. 188 pp. $10.00**

This report summarizes the results of a five year study to investigate methods required to return capability to land surface mined for coal in the Battle River area of central Alberta. Studies were conducted on: the amounts of subsoil required, the potential of gypsum and bottom ash to amend adverse soil properties, and the effects of slope angle and aspect. Forage and cereal crop growth was evaluated, as were changes in soil chemistry, density and moisture holding characteristics.

59. **RRTAC 89-6: Detailed Sampling, Characterization and Greenhouse Pot Trials Relative to Drilling Wastes in Alberta. T.M. Macyk, F.I. Nikiforuk, S.A. Abboud and Z.W. Widtman. 228 pp. $10.00**

This report summarizes a three-year study of the chemistry of freshwater gel, KCl, NaCl, DAP, and invert drilling wastes, both solids and liquids, from three regions in Alberta: Cold Lake, Eastern Slopes, and Peace River/Grande Prairie. A greenhouse study also examined the effects of adding various amounts of waste to soil on grass growth and soil chemistry. Methods for sampling drilling wastes are recommended.

60. **RRTAC 89-7: A User's Guide for the Prediction of Post-Mining Groundwater Chemistry from Overburden Characteristics. M.R. Trudell and D.C. Cheel. 55 pp. $5.00**

This report provides the detailed procedure and methodology that is required to produce a prediction of post-mining groundwater chemistry for plains coal mines, based on the soluble salt characteristics of overburden materials. The fundamental component of the prediction procedure is the geochemical model PHREEQE, developed by the U.S. Geological Survey, which is in the public domain and has been adapted for use on personal computers.

61. **RRTAC 90-1: Reclamation Research Annual Report - 1989. 62 pp. $5.00**

This annual report describes the expenditure of $480,000.00 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

62. **RRTAC 90-2: Initial Selection for Salt Tolerance in Rocky Mountain Accessions of Slender Wheatgrass and Alpine Bluegrass. R. Hermesh, J. Woosaree, B.A. Darroch, S.N. Acharya and A. Smreciu. 40 pp. $5.00**

Selected lines of slender wheatgrass and alpine bluegrass collected from alpine and subalpine regions of Alberta as part of another native grass project were evaluated for their ability to emerge in a saline medium. Eleven slender wheatgrass and 72 alpine bluegrass lines had a higher percentage emergence than the Orbit Tall Wheatgrass control (a commonly available commercial grass). This means that as well as an ability to grow in high elevation areas, these lines may also be suitable for use in areas where saline soil conditions are present. Thus, their usefulness for reclamation has expanded.

63. **RRTAC 90-3: Natural Plant Invasion into Reclaimed Oil Sands Mine Sites. Hardy BBT Limited. 65 pp. $5.00**

Vegetation data from reclaimed sites on the Syncrude and Suncor oil sands mines have been summarized and related to site and factors and reclamation methods. Natural invasion into sites seeded to agronomic grasses and legumes was minimal even after 15 years. Invasion was slightly greater in sites seeded to native species, but was greatest on sites that were not seeded. Invasion was mostly from agronomic species and native forbs; native shrub and tree invasion was minimal.

64. **RRTAC 90-4: Physical and Hydrological Characteristics of Ponds in Reclaimed Upland Landscape Settings and their Impact on Agricultural Capability. Moran, S.R., T.M. Macyk, M.R. Trudell and M.E. Pigot, Alberta Research Council. 76 pp. $5.00**

The report details the results and conclusions from studying a pond in a reclaimed upland site in Vesta Mine. The pond formed as a result of two factors: (1) a berm which channelled meltwater into a series of subsidence depressions, forming a closed basin; and (2) low hydraulic conductivity in the lower subsoil and upper spoil as a result of compaction during placement and grading which did not allow for rapid drainage of ponded water. Ponds such as this in the reclaimed landscape can affect agricultural capability by: (1) reducing the amount of farmable land (however, the area covered by these ponds in this region is less than half of that found in unmined areas); and, (2) creating the conditions necessary for the progressive development of saline and potentially sodic soils in the area adjacent to the pond.

65. **RRTAC 90-5: Review of the Effects of Storage on Topsoil Quality. Thurber Consultants Ltd., Land Resources Network Ltd., and Norwest Soil Research Ltd. 116 pp. $10.00**

The international literature was reviewed to determine the potential effects of storage on topsoil quality. Conclusions from the review indicated that storage does not appear to have any severe and longterm effects on topsoil quality. Chemical changes may be rectified with the use of fertilizers or manure. Physical changes appear to be potentially less serious than changes in soil quality associated with the stripping and respreading operations. Soil biotic populations appear to revert to pre-disturbance levels of activity within acceptable timeframes. Broad, shallow storage piles that are seeded to acceptable grass and legume species are recommended; agrochemical use should be carefully controlled to ensure soil biota are not destroyed.

66. **RRTAC 90-6: Proceedings of the Industry/Government Three-Lift Soils Handling Workshop. Deloitte & Touche. 168 pp. $10.00**

This report documents the results of a two-day workshop on the issue of three-lift soils handling for pipelines. The workshop was organized and funded by RRTAC, the Canadian Petroleum Association and the Independent Petroleum Association of Canada. Day one focused on presentation of government and industry views on the criteria for three-lift, the rationale and field data in support of three- and two-lift procedures, and an examination of the various soil handling methods in use. During day two, five working groups discussed four issues: alternatives to three-lift; interim criteria and suggested revisions; research needs; definitions of terms. The results of the workshop are being used by a government/industry committee to revise soils handling criteria for pipelines.

67. **RRTAC 90-7: Reclamation of Disturbed Alpine Lands: A Literature Review. Hardy BBT Limited. 209 pp. $10.00**

This review covers current information from North American sources on measures needed to reclaim alpine disturbances. The review provides information on pertinent Acts and regulations with respect to development and environmental protection of alpine areas. It also discusses: alpine environmental conditions; current disturbances to alpine areas; reclamation planning; site and surface preparation; revegetation; and, fertilization. The report also provides a list of research and information needs for alpine reclamation in Alberta.

68. **RRTAC 90-8: Plains Hydrology and Reclamation Project: Summary Report. S.R. Moran, M.R. Trudell, T.M. Macyk and D.B. Cheel. 105 pp. $10.00**

This report summarizes a 10-year study on the interactions of groundwater, soils and geology as they affect successful reclamation of surface coal mines in the plains of Alberta. The report covers: Characterization of the Battle River and Wabamun study areas; Properties of reclaimed materials and landscapes; Impacts of mining and reclamation on post-mining land use; and, Implications for reclamation practice and regulation. This project has led to the publication of 18 RRTAC reports and 22 papers in conference proceedings and refered journals.

69. **RRTAC 90-9: Literature Review on the Disposal of Drilling Waste Solids. Monenco Consultants Limited. 83 pp. $5.00**

This report reviews the literature on, and government and industry experience with, burial of drilling waste solids in an Alberta context. The review covers current regulations in Alberta, other provinces, various states in the US and other countries. Definitions of various types of burial are provided, as well as brief summaries of other possible disposal methods. Environmental concerns with the various options are presented as well as limited information on costs and monitoring of burial sites. The main conclusion of the work is that burial is still a viable option for some waste types but that each site and waste type must be evaluated on its own merits.

70. **RRTAC 90-10: Potential Contamination of Shallow Aquifers by Surface Mining of Coal. M.R. Trudell, S.R. Moran and T.M. Macyk. 75 pp. $5.00**

This report presents the results of a field investigation of the movement of salinized groundwater from a mined and reclaimed coal mine near Forestburg into an adjacent unmined area. The movement is considered to be an unusual occurrence resulting from a combination of a hydraulic head that is higher in the mined area than in the adjacent coal aquifer, and the presence of a thin surficial sand aquifer adjacent to the mine. The high hydraulic head results from deep ponds in the reclaimed landscape that recharge the base of the spoil.

71. **RRTAC 91-1: Reclamation Research Annual Report - 1990. Reclamation Research Technical Advisory Committee. 69 pp. $5.00**

This annual report describes the expenditure of $499 612 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program. The report lists the 70 research reports published under the program.